CERES Cloud Properties at ARM Sites

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This presentation includes:

1) Ed2 and Ed4 Cloud temp and heights at ARM SGP and NSA
2) Arctic cloud microphysical properties over snow-free and snow surface, as well as a radiation closure study
3) A radiation closure study over ARM sites for clear-sky.

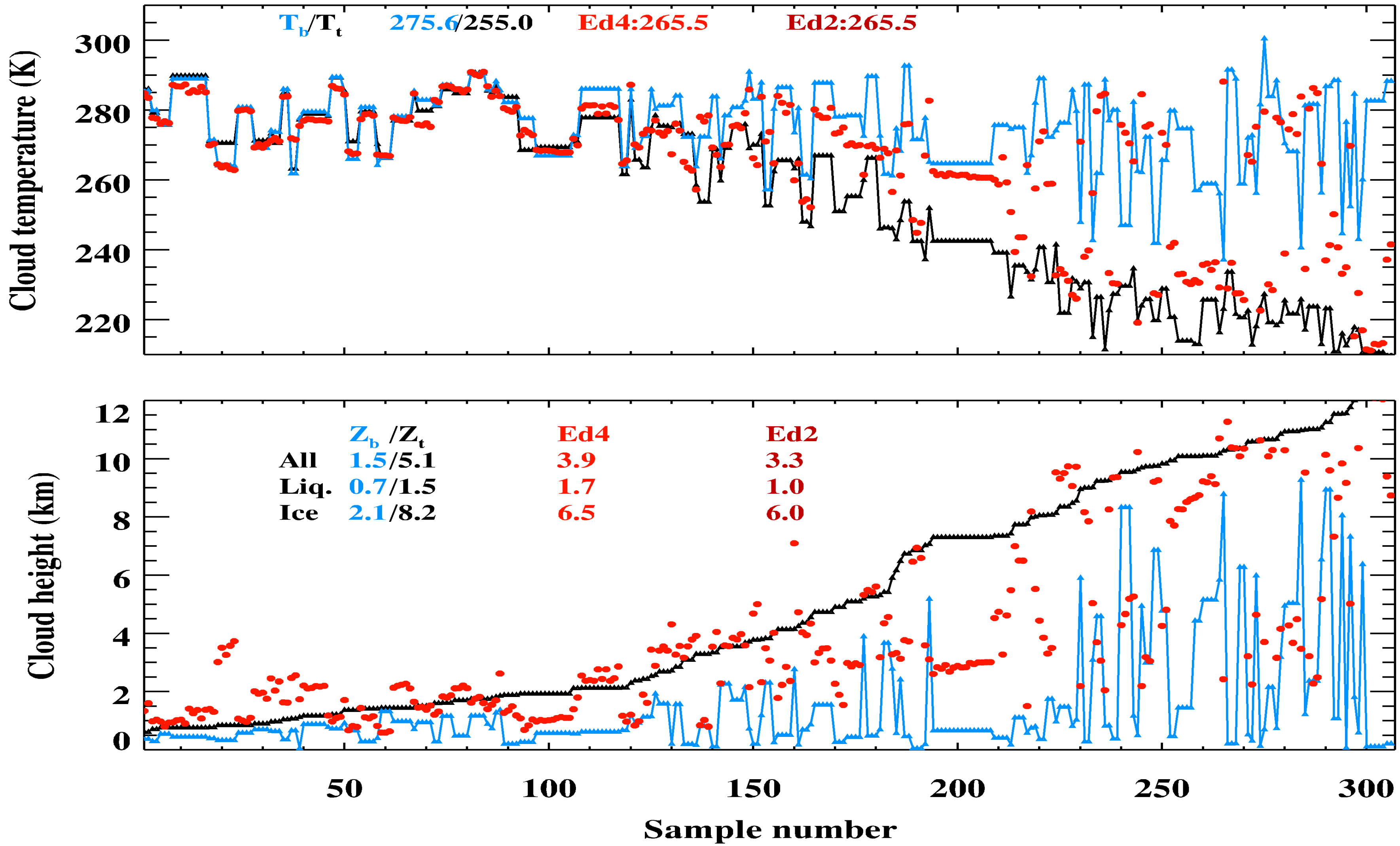
Motivation

- Any significant differences of cloud macrophysical properties between Ed4 and Ed2 over SGP and NSA;
- Any significant differences of cloud microphysical properties between Ed4 and Ed2 over the snow and non-snow covered surfaces at NSA;
- Understand the complexities of cloud microphysical retrievals that may be impacted by surface albedo;
- Understand the physics behind any adjustments of cloud properties, which may significantly impact the radiative fluxes.

Objectives

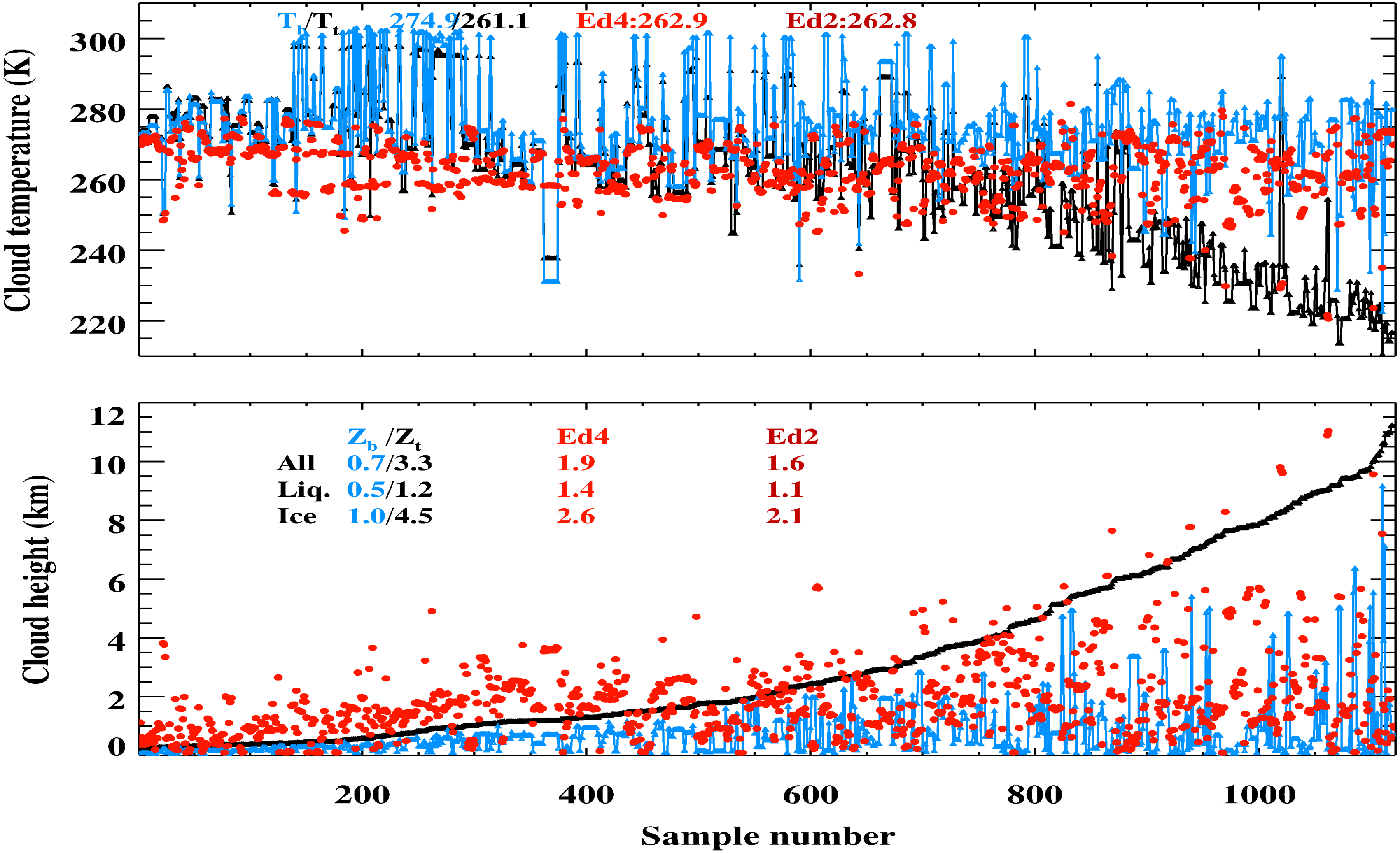
- Update of Ed4/Ed2 cloud macrophysics of all types of clouds over ARM SGP and NSA sites.
- Ed4/Ed2 Cloud microphysics retrievals over snow and non-snow surfaces, as well as the impact of surface albedo on cloud retrievals at ARM NSA.
- Can we reach a radiation closure study? That is, Can the RTM calculated radiative fluxes agree with both CERES observed TOA fluxes and ARM surface fluxes?
- Under clear sky: TOA and Surface fluxes over ARM sites.

Ed4 T_{eff}/H_{eff} vs. ARM T_b/T_t and H_b/H_t at SGP (Daytime)



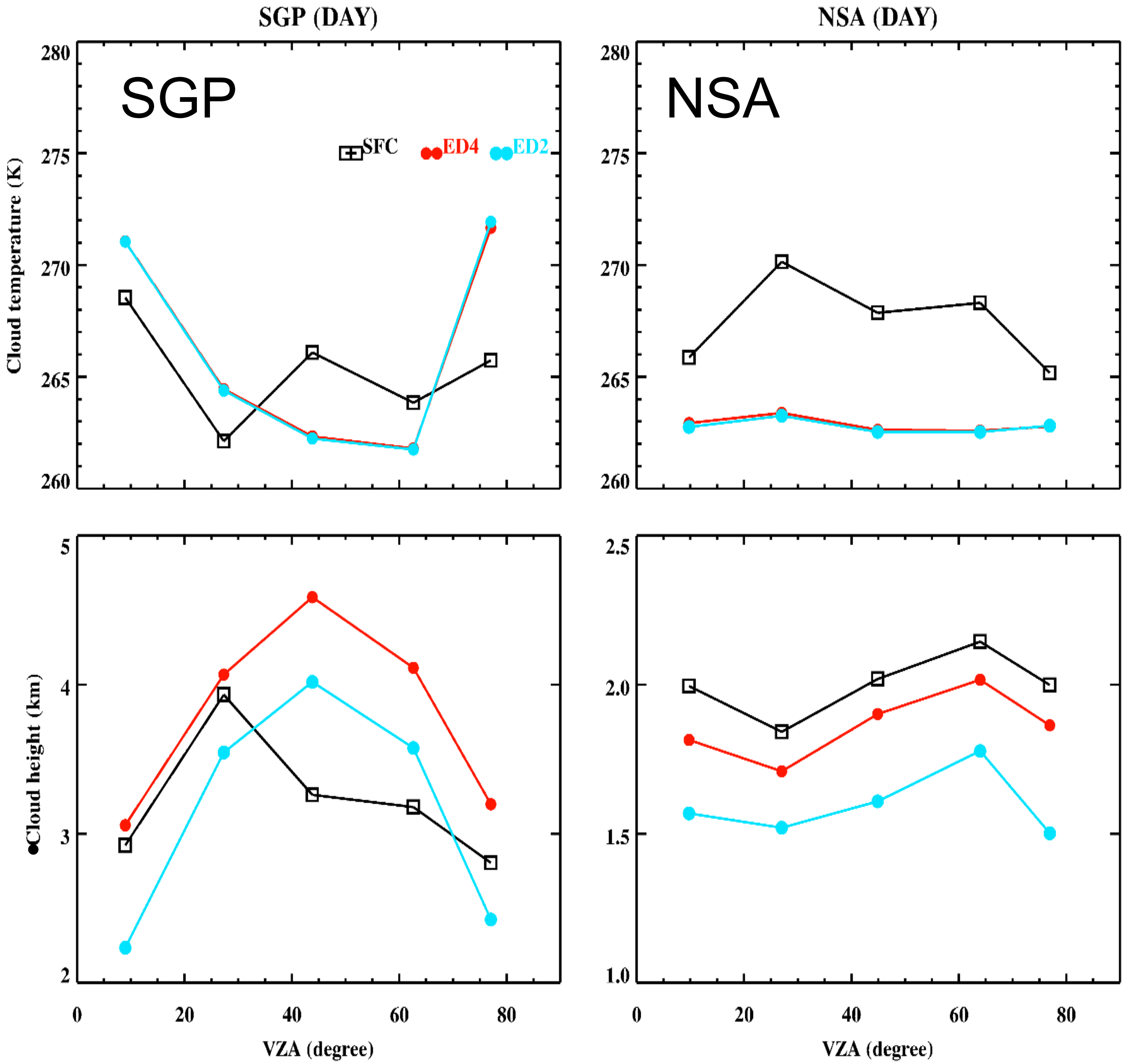
- **For all types of clouds, the mean Ed4 T_{eff} is close to of the cloud center temp, and H_{eff} falls between the cloud center and top, however, the mean Ed4 H_{eff} is 200 m higher than H_t for low-level clouds.**
- **The mean Ed2 T_{eff} is same as Ed4, but it mean Z_{eff} is 600 m lower than Ed4.**

Ed4 T_{eff}/H_{eff} vs. ARM T_b/T_t and H_b/H_t at NSA (Daytime)



- **For all types of clouds, both mean Ed4 and Ed2 T_{eff} are close to cloud-base temp, and their mean H_{eff} locate below the cloud center.**
- **For low clouds, the mean Ed4 H_{eff} is 200 m higher, but Ed2 is 100 m lower than H_t.**
- **For high clouds, both mean Ed4 and Ed2 H_{eff} are below the cloud center.**

Sensitivities of Cloud temp and height to VZA



- **Ed4 and Ed2 T_{eff} are close to each other at both SGP and NSA sites.**
- **Both Ed4 and Ed2 T_{eff} and H_{eff} are independent of VZA at NSA, but strongly depend on VZA at SGP.**
- **ARM cloud temp and height are weakly dependent of VZA at two sites**

A Radiation Closure Study of Arctic Stratus Cloud Microphysical Properties using the collocated satellite-surface data and Fu-Liou Radiative Transfer Model

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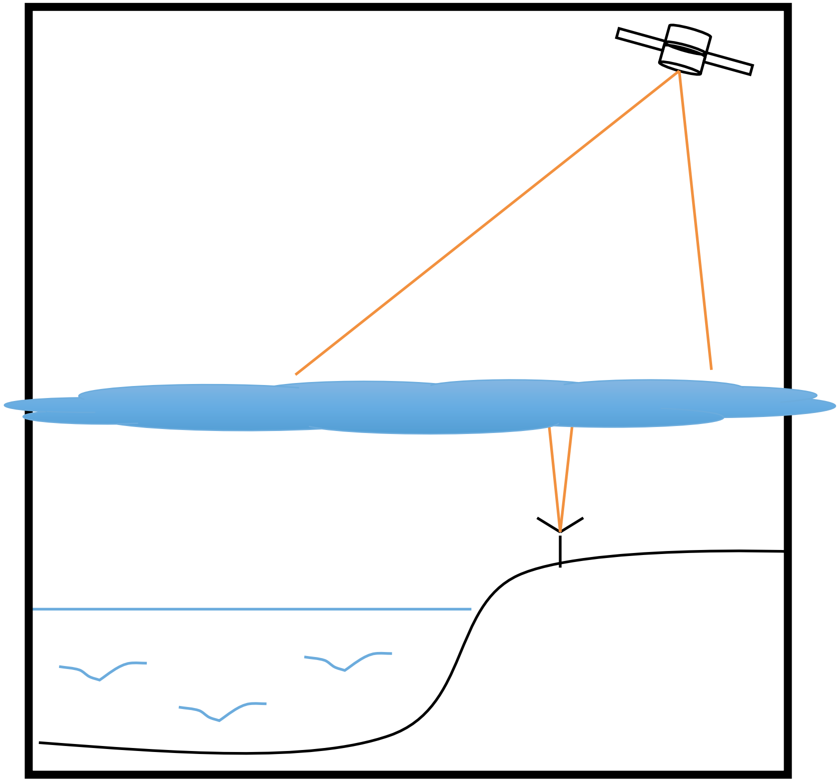
Paper submitted to JGR.

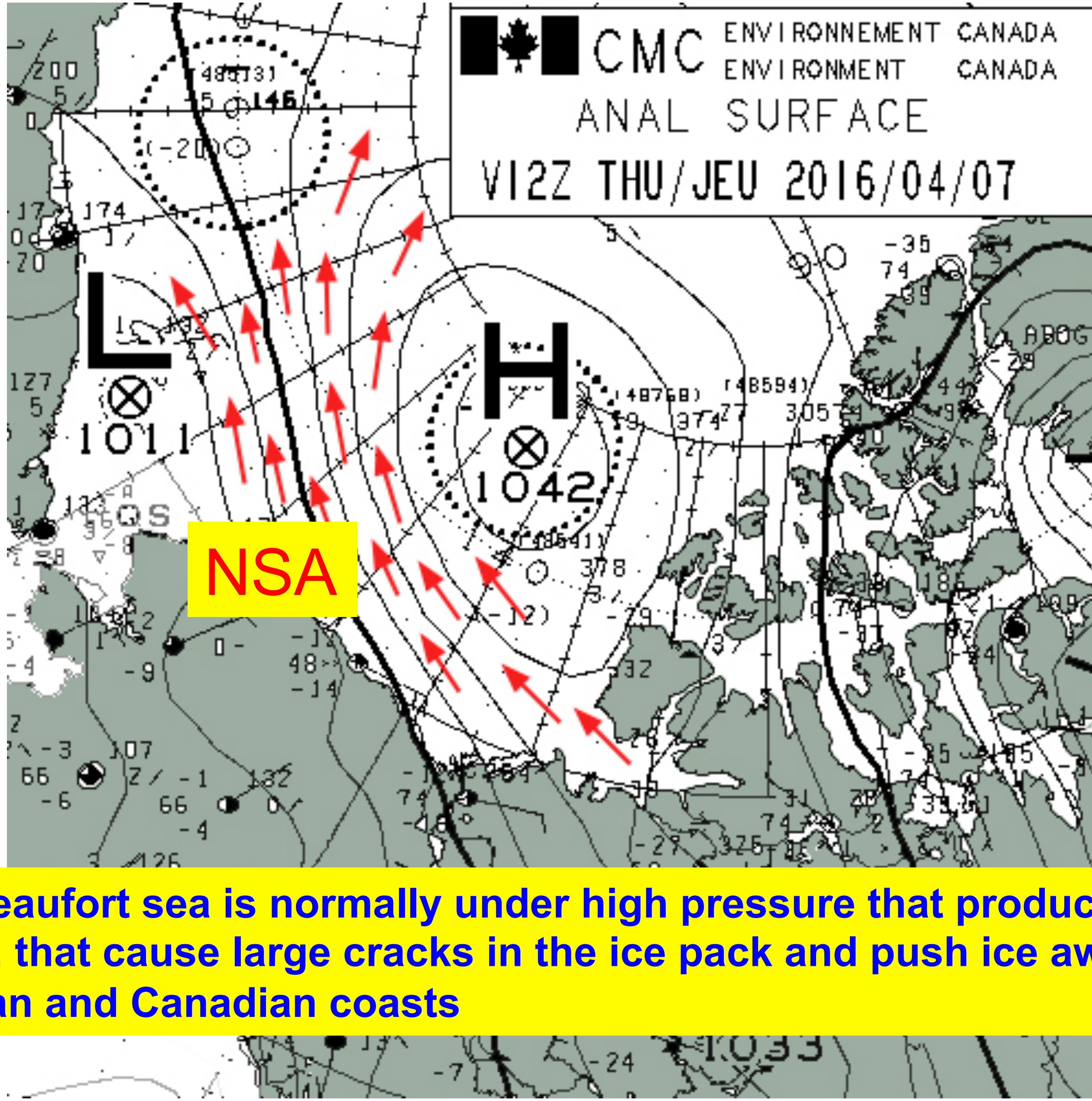
Domain representativeness of the ARM NSA PSP-measured surface albedo

30 km

30 km



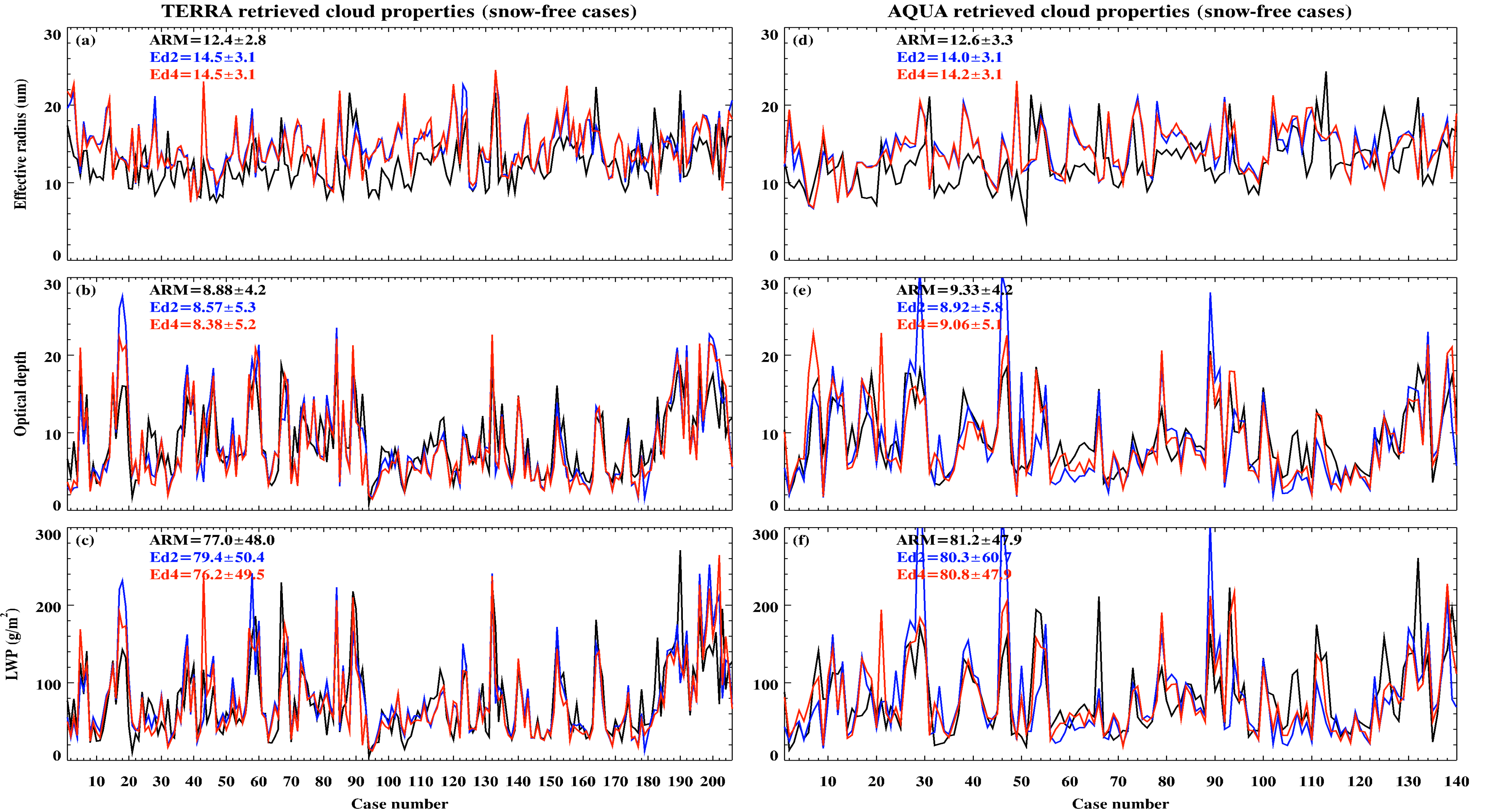
→A grid box (30 km x 30 km) includes half ocean and half land surface.
→The adjusted surface albedo=0.8*ARM measured R_{sfc} due to leads open up around Barrow during Spring.



The Beaufort sea is normally under high pressure that produces strong winds, that cause large cracks in the ice pack and push ice away from the Alaskan and Canadian coasts

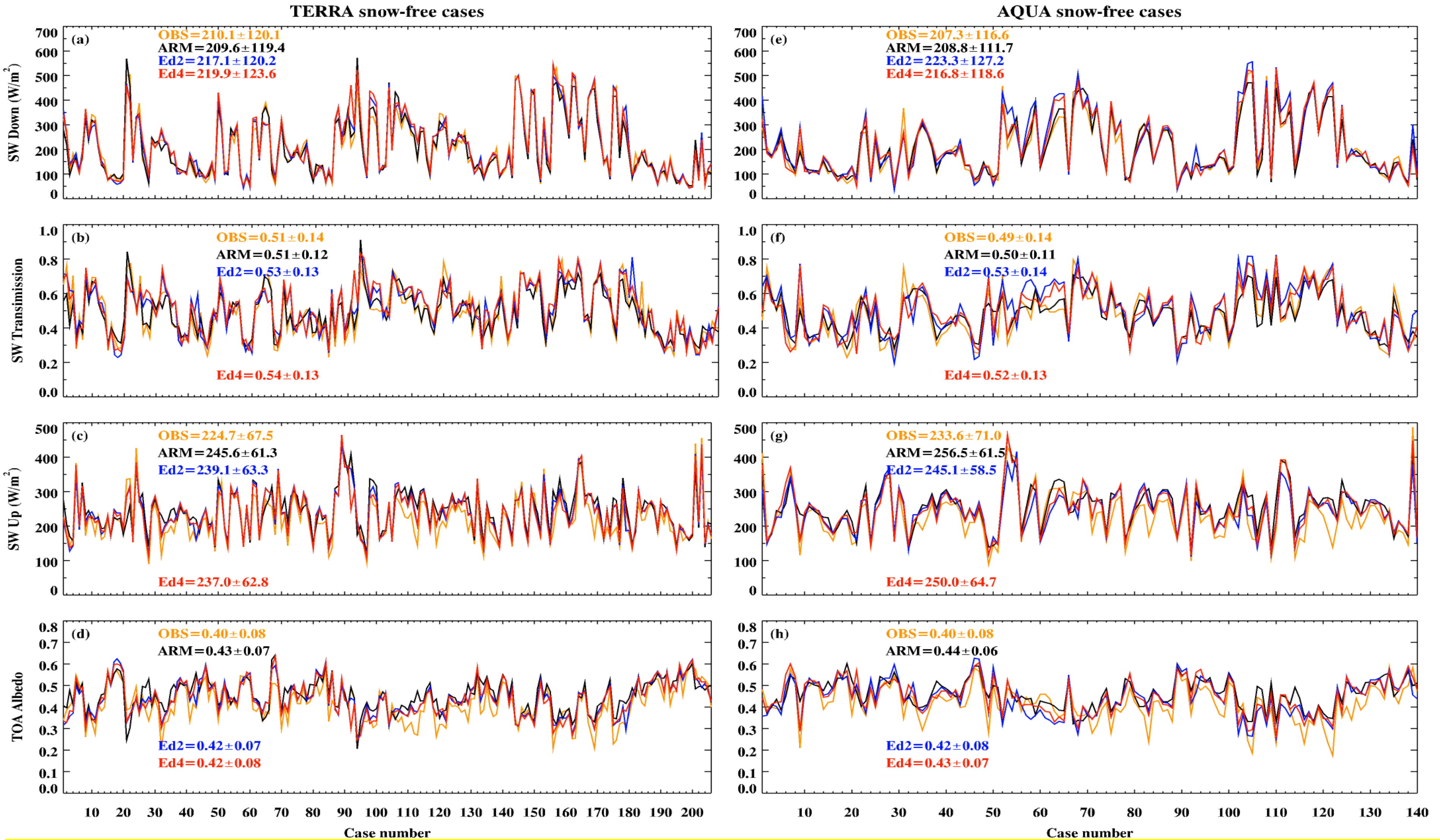
http://neven1.typepad.com/.a/6a0133f03a1e37970b01b8d1c04efa970c-800wi

Comparisons of Cloud Microphyscial Properties for snow-free cases



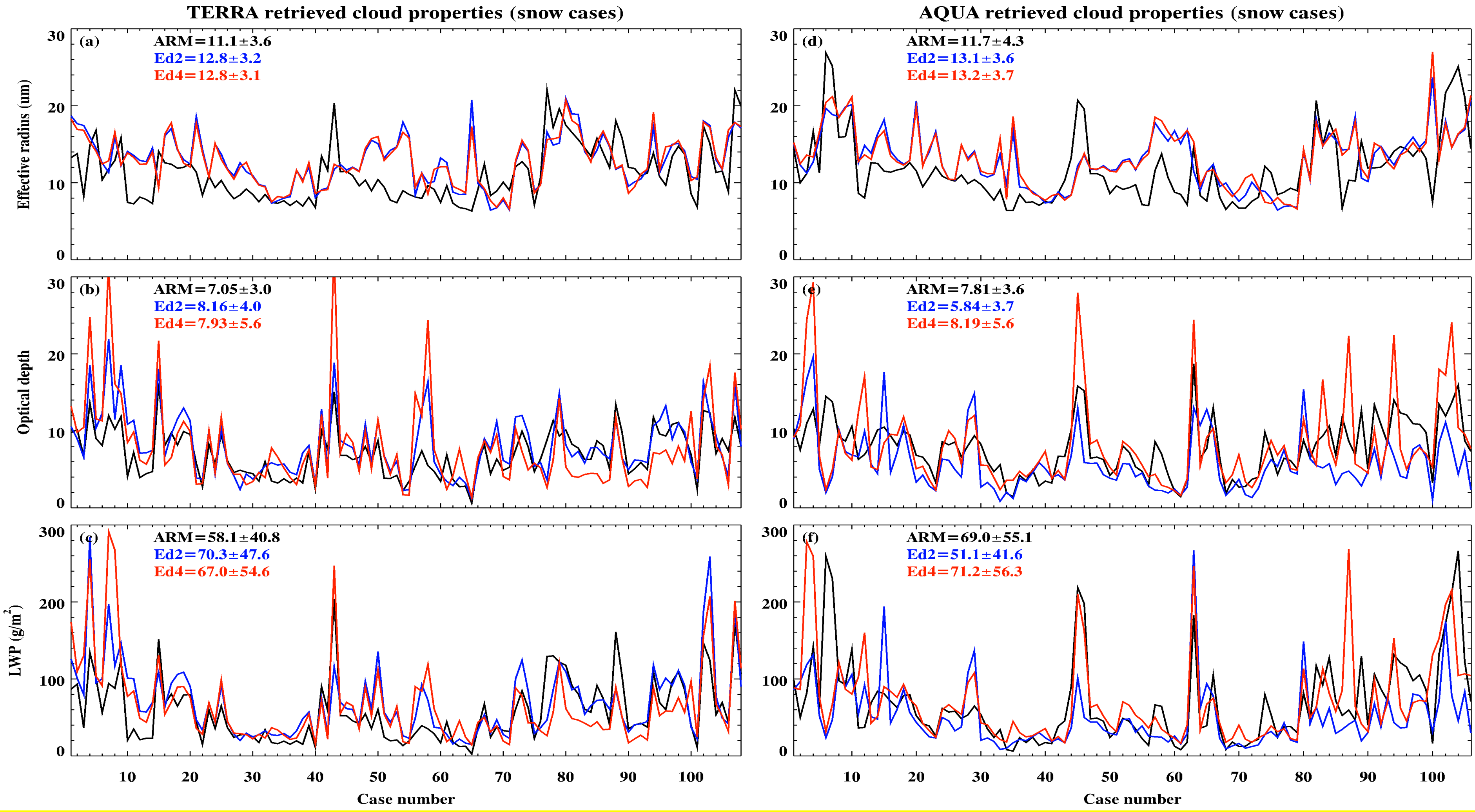
- **Ed4 and Ed2 τ and LWP retrievals from both Terra and Aqua are identical and have excellent agreement with ARM retrievals, but their r_e means are 1.8 µm greater than the ARM mean (12.5 µm).**
- **Using adjusted R_{sfc} has no impact to ARM cloud retrievals.**

Comparisons of SW_down at SFC and SW_up at TOA for snow-free



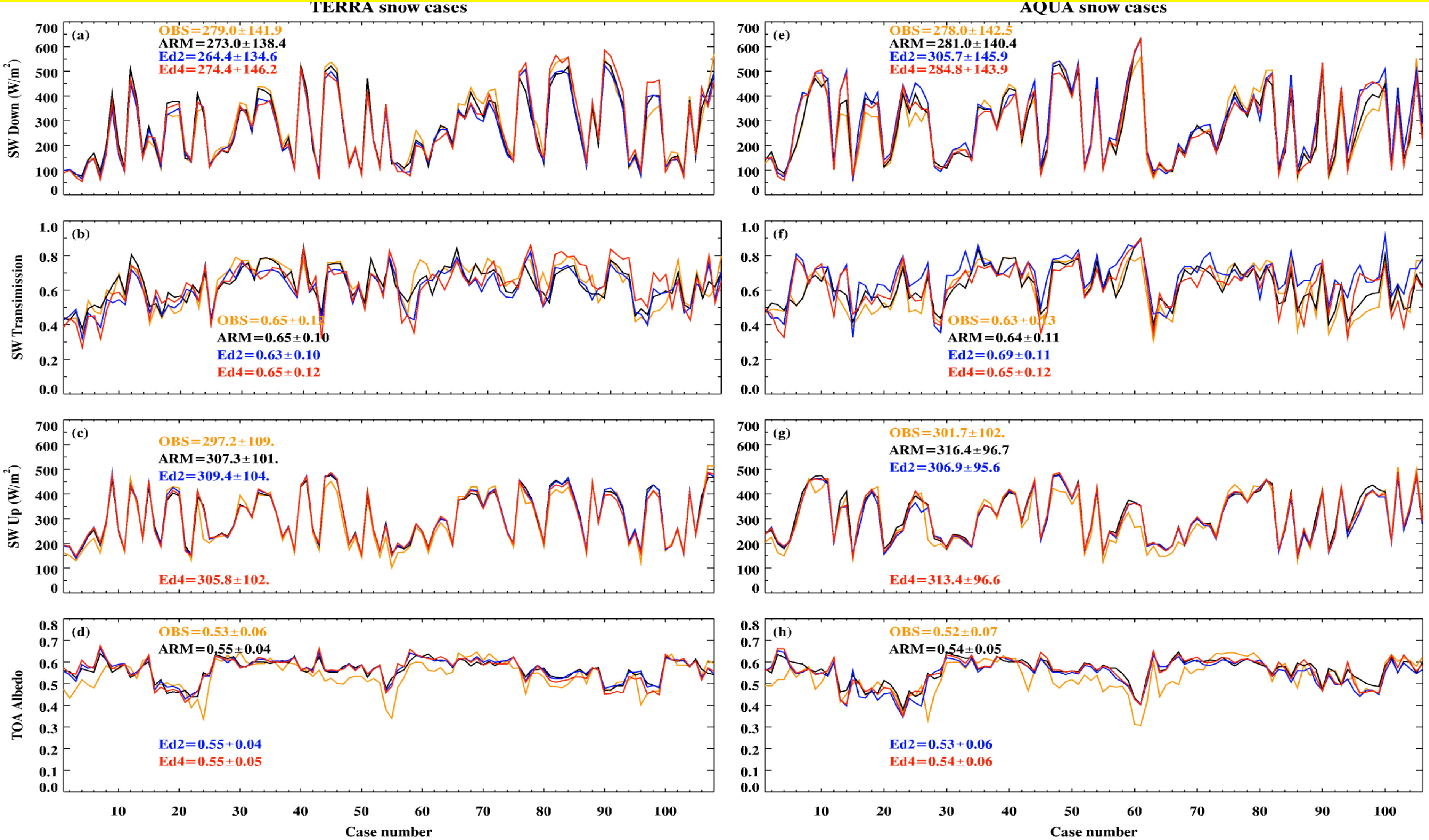
- **RTM calculated SW_down flxues at SFC agree with ARM PSP observations within 10 Wm^{-2}, transmission within 0.03, TOA albedos agree within 0.02 with CERES observations.**
- **Using adjusted R_{sfc} makes the SW differences ~ 4 Wm^{-2} smaller**

Comparisons of Cloud Microphyscial Properties for snow cases



- **The r_e, τ, and *LWP* comparisons between CERES Ed4/Ed2 and ARM also agree well each other but their values are slightly smaller than their corresponding snow-free counterparts.**
- **Ed4 cloud retrievals have a significant improvement than Ed2 results**
- **Using adjusted R_{sfc} makes ARM cloud retrievals close to CM retrievals.**

Comparisons of SW_down at SFC and SW_up at TOA for snow cases



- **Using original R_{sfc} values in the RTM calculations, the mean $SW^{\downarrow}_{sfc}$ and $SW^{\uparrow}_{TOA}$ flux differences are 16.4 and 43.8 Wm^{-2}, respectively.**
- **The differences are reduced to -1.8 and 11.8 Wm^{-2} using adjusted R_{sfc} values.**
- **We conclude that the adjusted R_{sfc} can represent the large CERES FOV.**

Snow-free cases		TOA SW↑		R_{TOA}		SFC SW↓$_{cly}$		γ	
		0.8α	1.0α	0.8α	1.0α	0.8α	1.0α	0.8α	1.0α
Terra (206)	**OBS**	**224.7**		**0.40**		**210.1**		**0.51**	
	ARM	245.6	249.8	0.43	0.44	209.6	212.4	0.51	0.52
	Ed2	239.1	243.4	0.42	0.43	217.1	220.1	0.53	0.54
	Ed4	237.0	241.5	0.42	0.43	219.9	222.9	0.54	0.55
Aqua	**OBS**	**233.6**		**0.40**		**207.3**		**0.49**	
	ARM	256.4	260.6	0.44	0.45	208.8	211.7	0.50	0.50

➢ **The question is how well we can do the flux comparisons under clear-sky conditions? That is, how well both RTM calculated TOA and surface fluxes agree with CERES and ARM observations over different ARM sites?**

Snow cases		TOA SW↑		R_{TOA}		SFC SW↓$_{cly}$		γ	
		0.8α	1.0α	0.8α	1.0α	0.8α	1.0α	0.8α	1.0α
Terra (108)	**OBS**	**297.2**		**0.53**		**279.0**		**0.63**	
	ARM	307.3	342.8	0.55	0.62	273.0	280.3	0.64	0.66
	Ed2	309.4	338.5	0.55	0.61	264.4	291.1	0.69	0.69
	Ed4	305.8	336.6	0.55	0.60	274.4	299.7	0.65	0.71
Aqua (106)	**OBS**	**301.7**		**0.52**		**278.0**		**0.63**	
	ARM	316.4	350.9	0.54	0.60	281.0	288.6	0.64	0.65
	Ed2	306.9	340.4	0.53	0.59	305.7	327.7	0.69	0.74
	Ed4	313.4	343.4	0.54	0.59	284.8	310.1	0.65	0.70

Calculating Clear-sky Radiative Fluxes with Inputs from hybrid and MERRA-2 Atmospheric Profiles

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Xiquan Dong[1], Baike Xi[1], Jonathan Jiang[2] , and Norman Loeb[3]

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[2]Jet Propulsion Lab

[3]NASA Langley Research Center

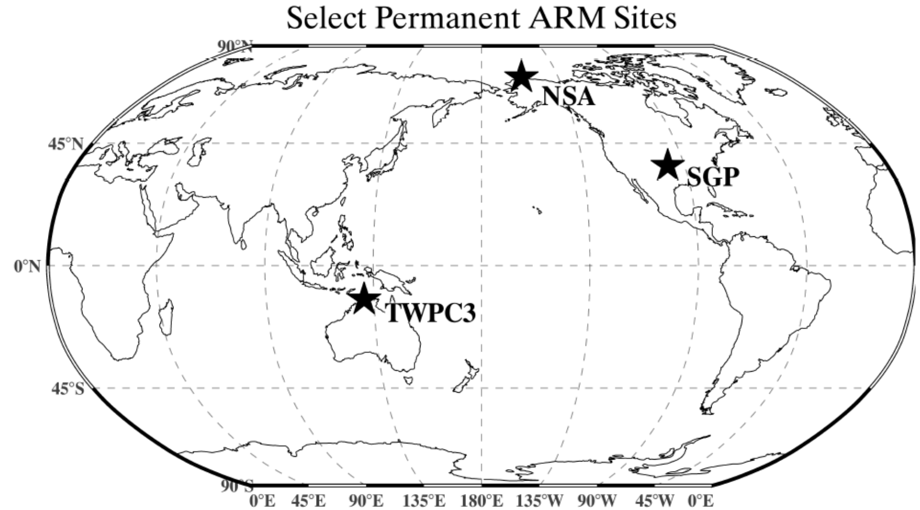
***Submitted to JGR: Atmospheres**

Motivation and Objectives

- **Estimate the effect of clouds on the radiation budget**
  - **Need better constraints and understanding of the clear-sky radiation budget**
- **Surface radiation products are computed using modeled (GEOS5 GCM) atmospheric profiles of temperature and humidity**
- **MERRA-2 also uses this model to produce regularly gridded (time and space) products of temperature and humidity profiles**
  - **Are these data appropriate as input in calculating clear-sky radiative fluxes?**

- **Evaluate the MERRA-2 clear-sky temperature, ozone, and water vapor profiles at 3 ARM sites (SGP, NSA, TWPC3) using a newly generated "hybrid" dataset**
- **Radiation closure study: calculate clear-sky radiative fluxes with observational (CERES and ARM) constraints**
  - **Includes tuning of the calculated fluxes**
  - **Understand the sensitivity of the calculated fluxes to changes in surface albedo, aerosol optical depth, and skin temperature**

Study Design



Where: 3 ARM sites

When: 08/2004 – 12/2012

Hybrid Profiles

Temperature and Water Vapor: MLS (above 100 hPa) and ARM merged sounding (below 100 hPa)

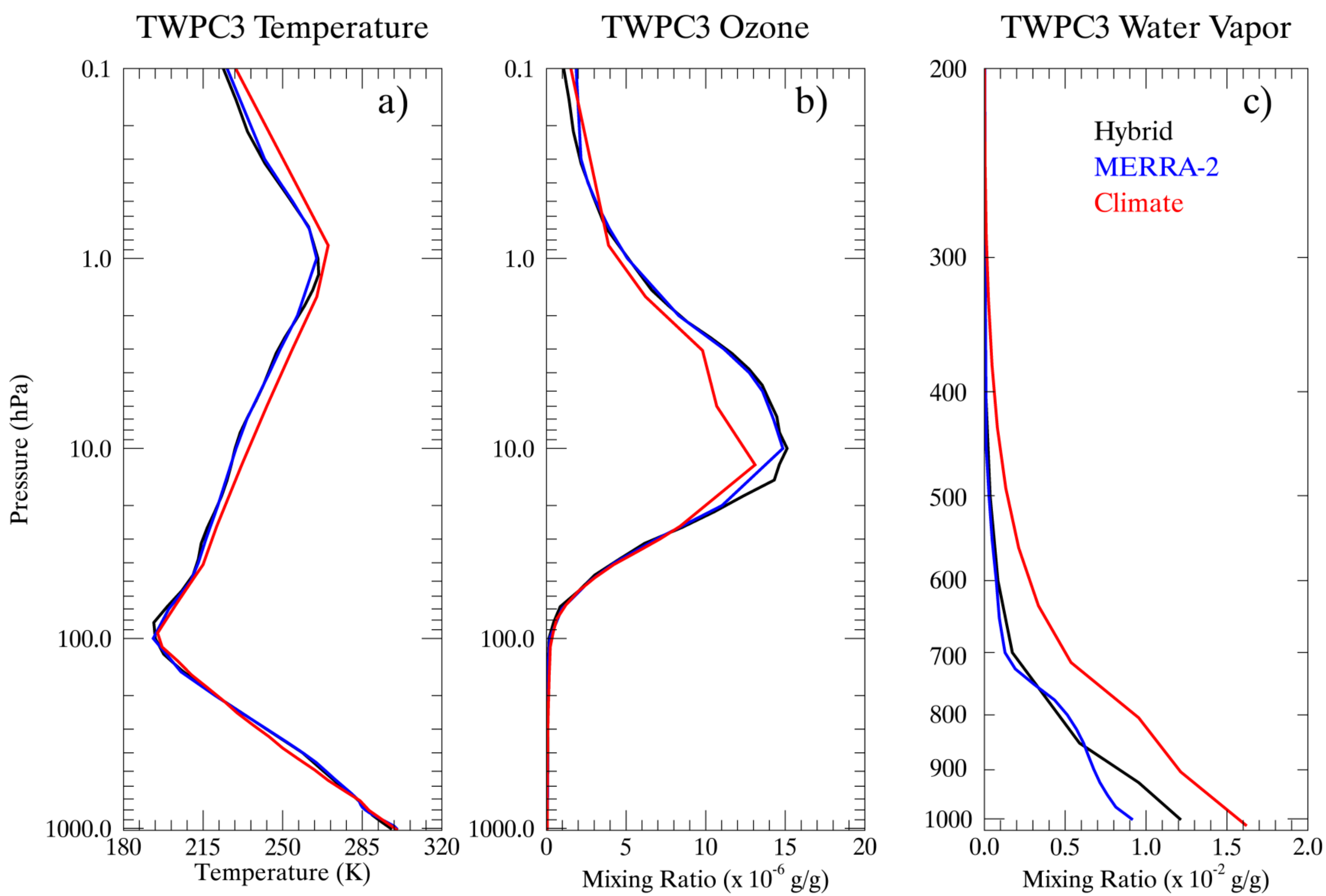
Ozone: MLS (above 260 hPa) and AIRS (below 260 hPa)

Clear-sky Screening

1) ARM ARSCL cloud product (3-hr period centered at overpass time
2) CERES SSF clear-sky fraction >90% at overpass time

Site	SGP	NSA		TWPC3
		Snow ($\alpha \geq 0.3$)	Snow-free ($\alpha < 0.3$)	
# Total Cases	35	12	5	13
# Daytime	14	7	5	9
# Nighttime	21	5	0	4

Evaluation of MERRA-2 T, O3, and H2O



- **Good agreement between MERRA-2 and the Hybrid profiles for temperature and ozone at the three sites**
- **Water vapor is slightly dry in the troposphere**

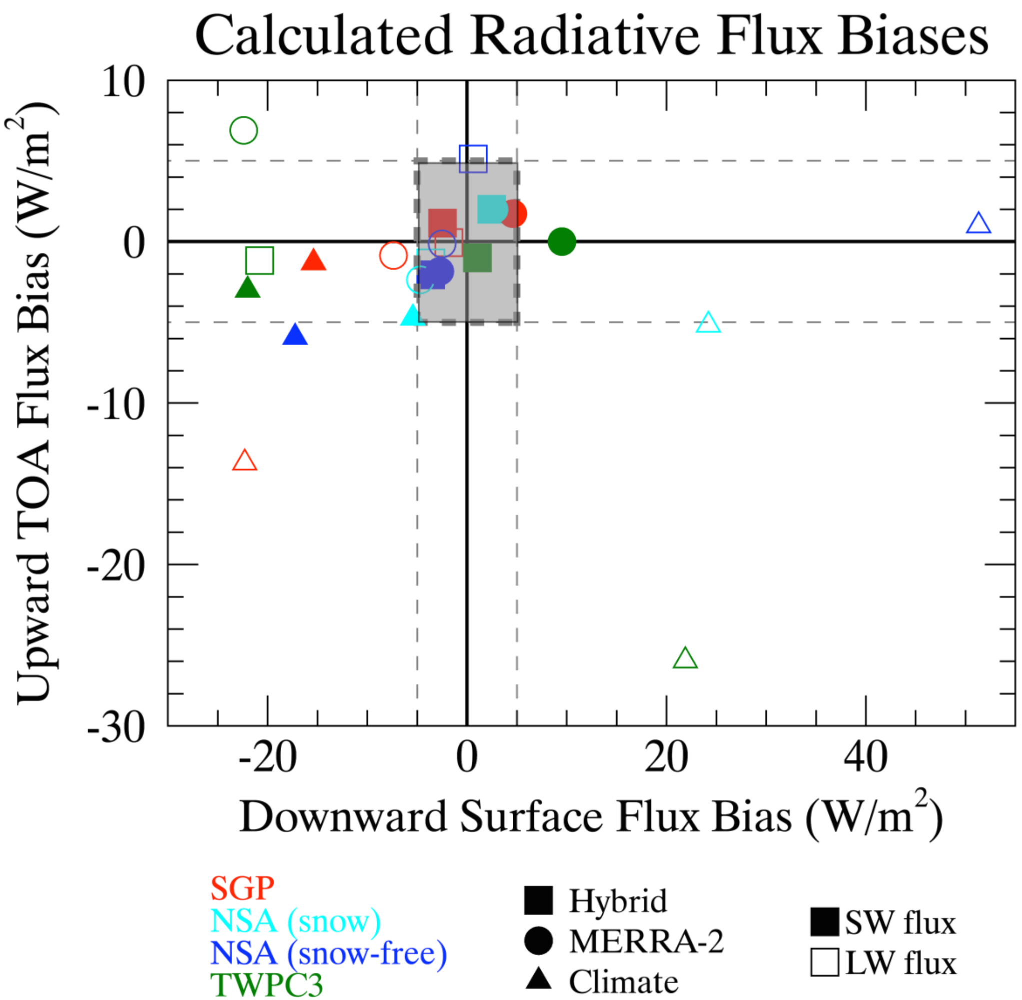
Tuning the calculated fluxes

- **Initially, calculated fluxes were highly biased against instantaneous CERES SSF and ARM results…**

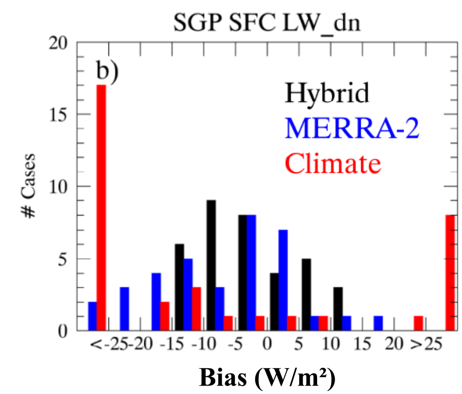
	SGP	NSA		TWPC3
		Snow ($\alpha \geq 0.3$)	Snow-free ($\alpha < 0.3$)	
Albedo	−10%	−15%	30%	−45%
AOD_{abs}/AOD_{scat}	10%	10%	10%	25%
Skin_T	N/A	N/A	N/A	N/A

- **Tuning the surface albedo accounts for some of the inhomogeneity in the surface characteristics within the CERES swath (i.e., land type, sea ice/snow, ocean/land contrast)**
  - **Increasing the surface albedo *increases* the clear-sky surface SW_dn and TOA SW_up fluxes, with a stronger sensitivity in the *TOA* component**
- **We tune the aerosol ratio (AOD_{abs}/AOD_{scat}) due to inhomogeneous aerosol distribution**
  - **Increasing the aerosol ratio *decreases* the clear-sky surface SW_dn and TOA SW_up fluxes, with a stronger sensitivity in the *surface* component**

Results: [Tuned] Calculated Fluxes



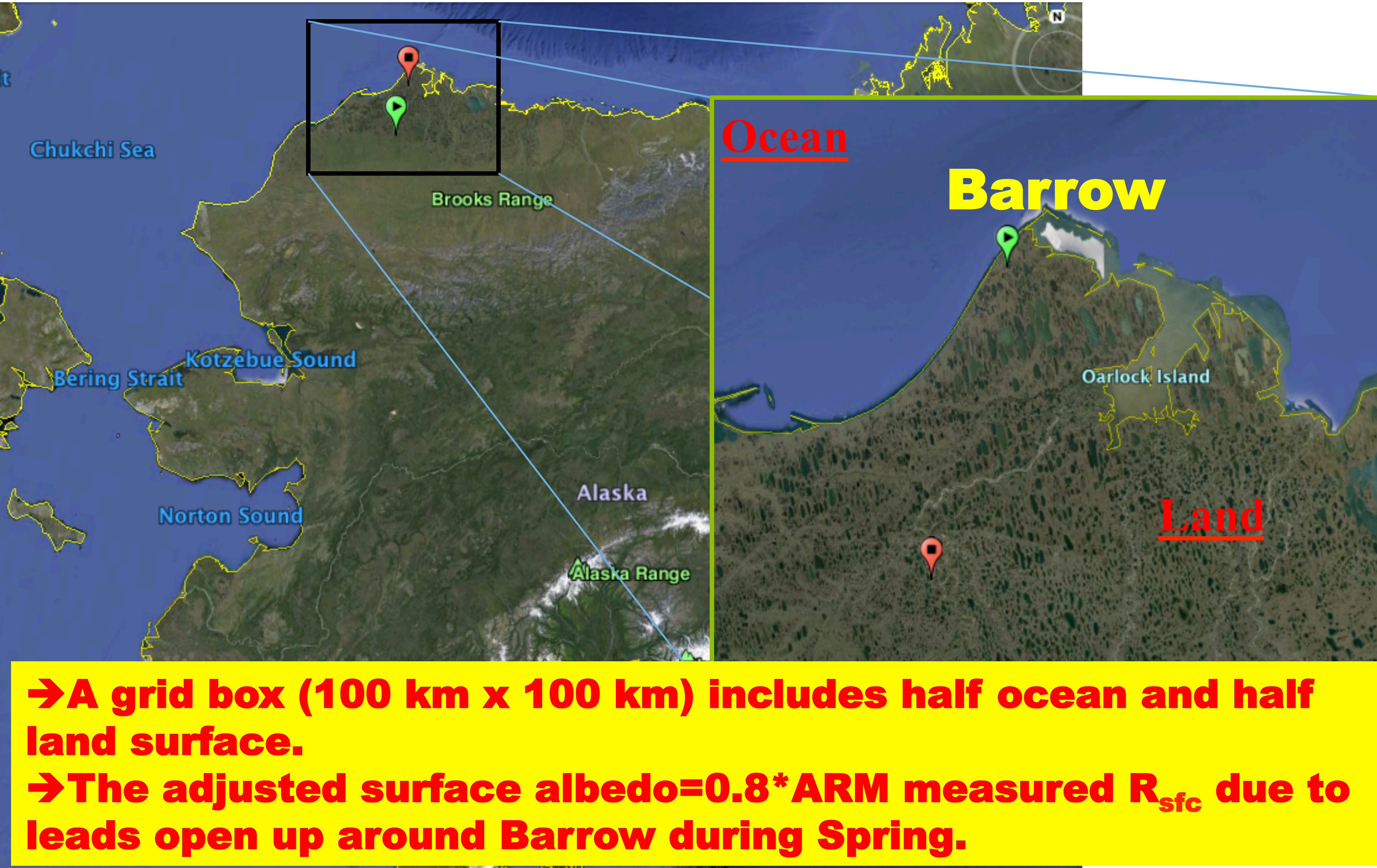
- **Most [tuned] average calculated flux biases are less than 5 W/m² when using the hybrid (squares) and MERRA-2 (circles) profiles as input**
- **Error compensation is evident**



- **Input of accurate atmospheric profiles is important in calculating clear-sky surface and TOA radiative fluxes**

Supplemental

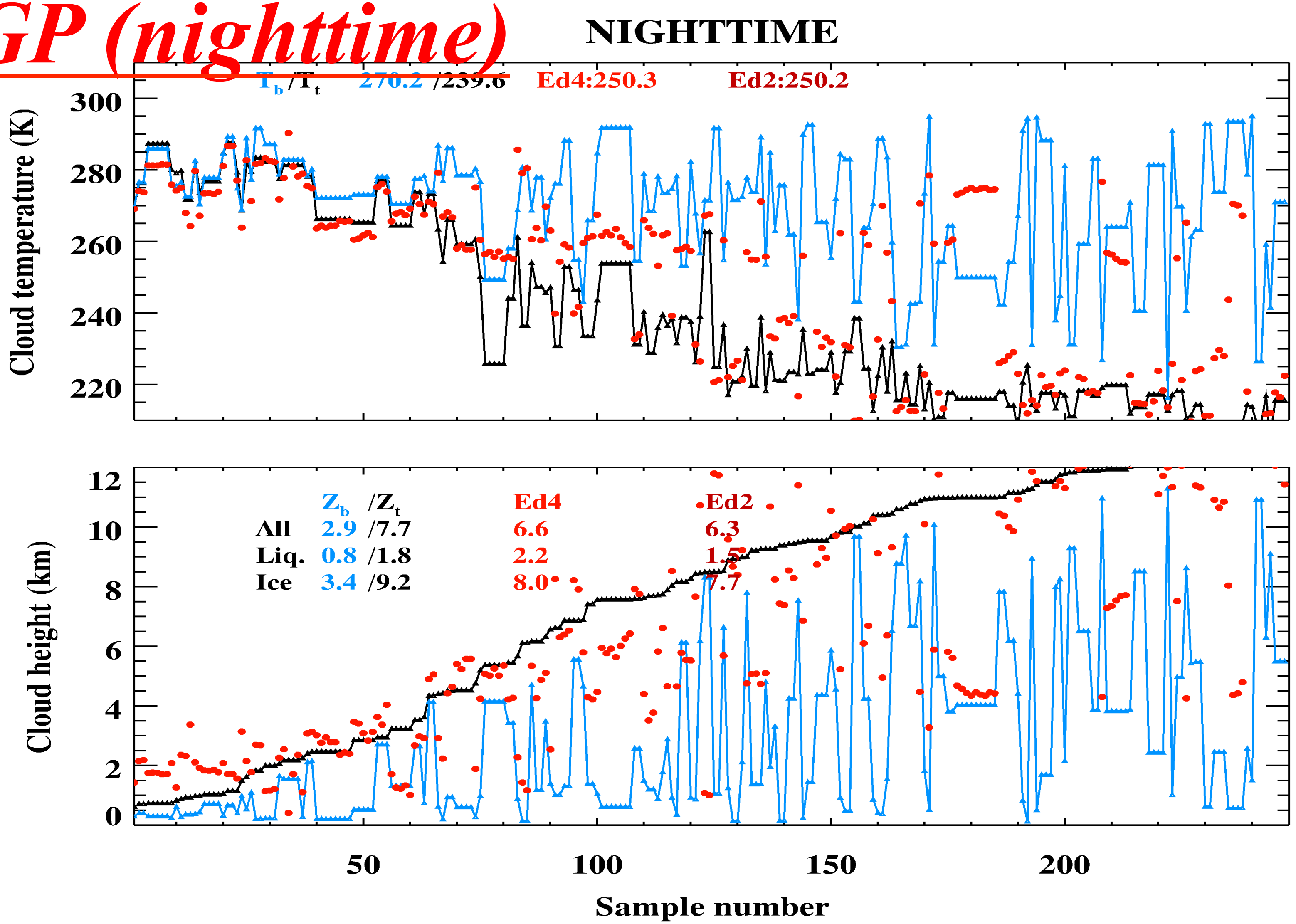
Domain representativeness of the ARM NSA PSP-measured surface albedo



→A grid box (100 km x 100 km) includes half ocean and half land surface.

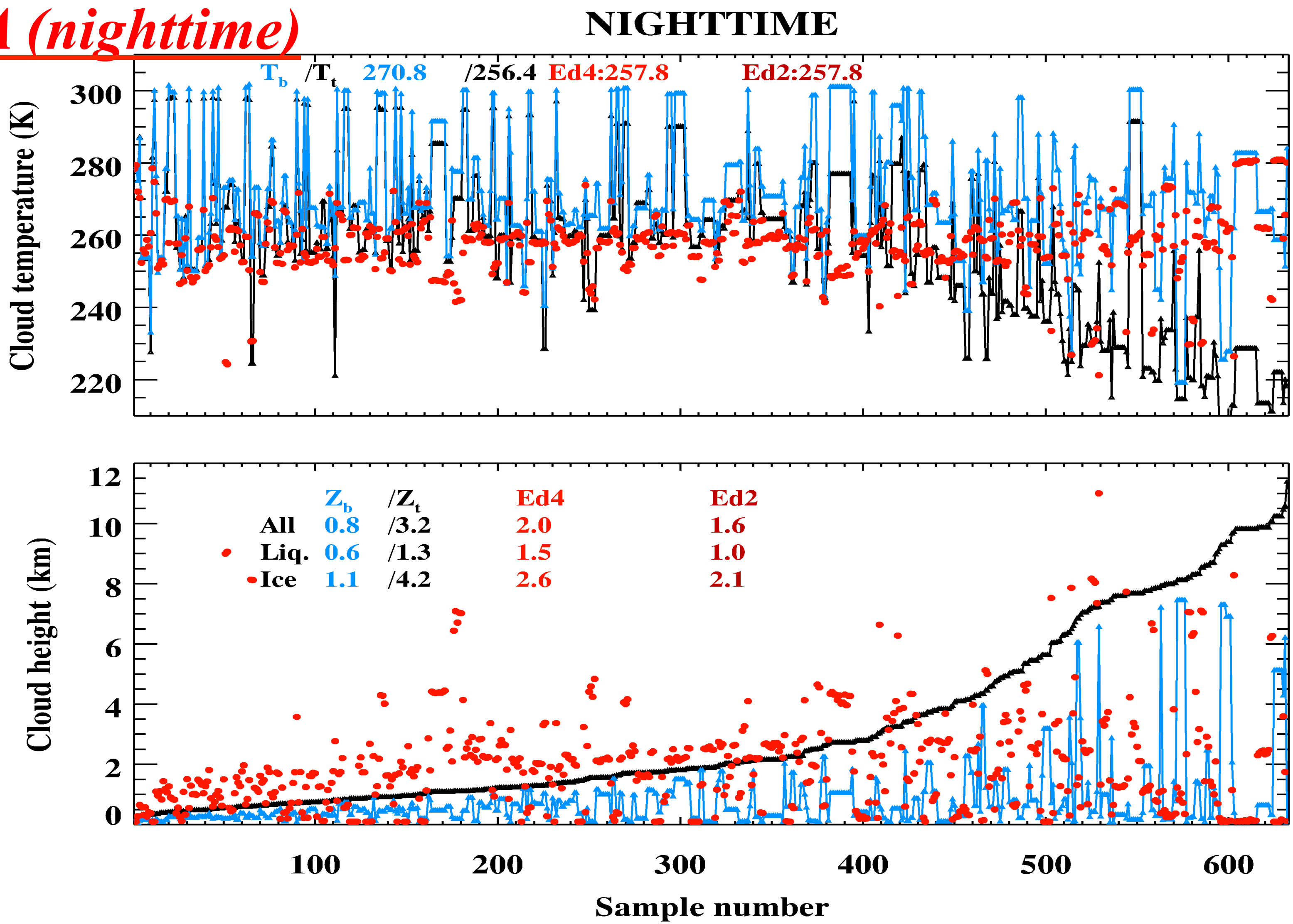
→The adjusted surface albedo=0.8*ARM measured R_{sfc} due to leads open up around Barrow during Spring.

SGP (nighttime)

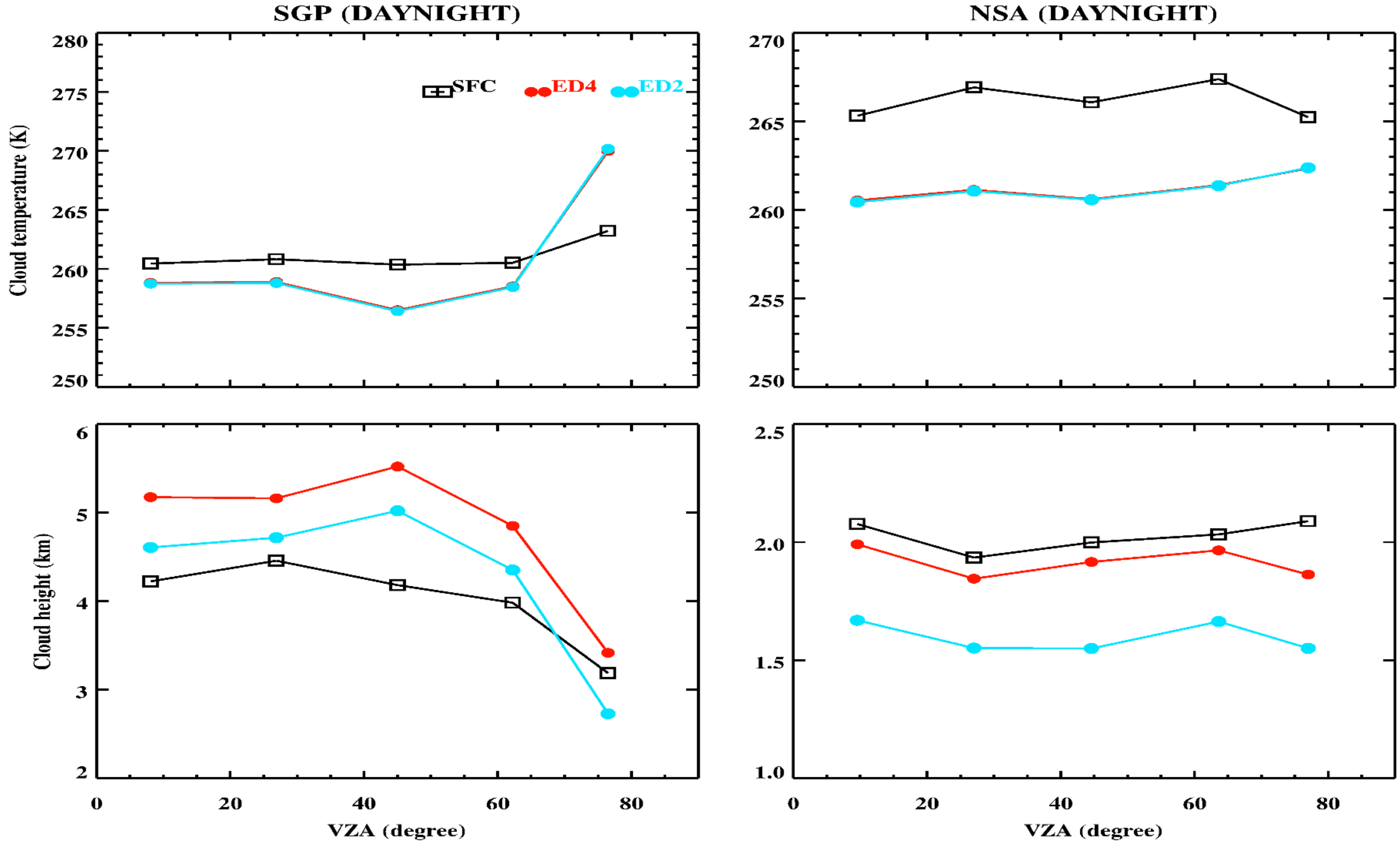


- For all types of clouds, T_{eff} of both CM Ed2 and Ed4 is 4.6 K lower than to T_{center}=0.5x(T_b+T_t) ~255 K;
- Z_{eff} of CM Ed2 for all types of clouds are all lower than Z_t;
- Z_{eff} of CM Ed2 for all types of clouds are all lower than Z_t except single layer liquid clouds;
- For single layer liquid clouds, the Z_{eff} of Ed4 is ~ 400 meters higher than Z_t.

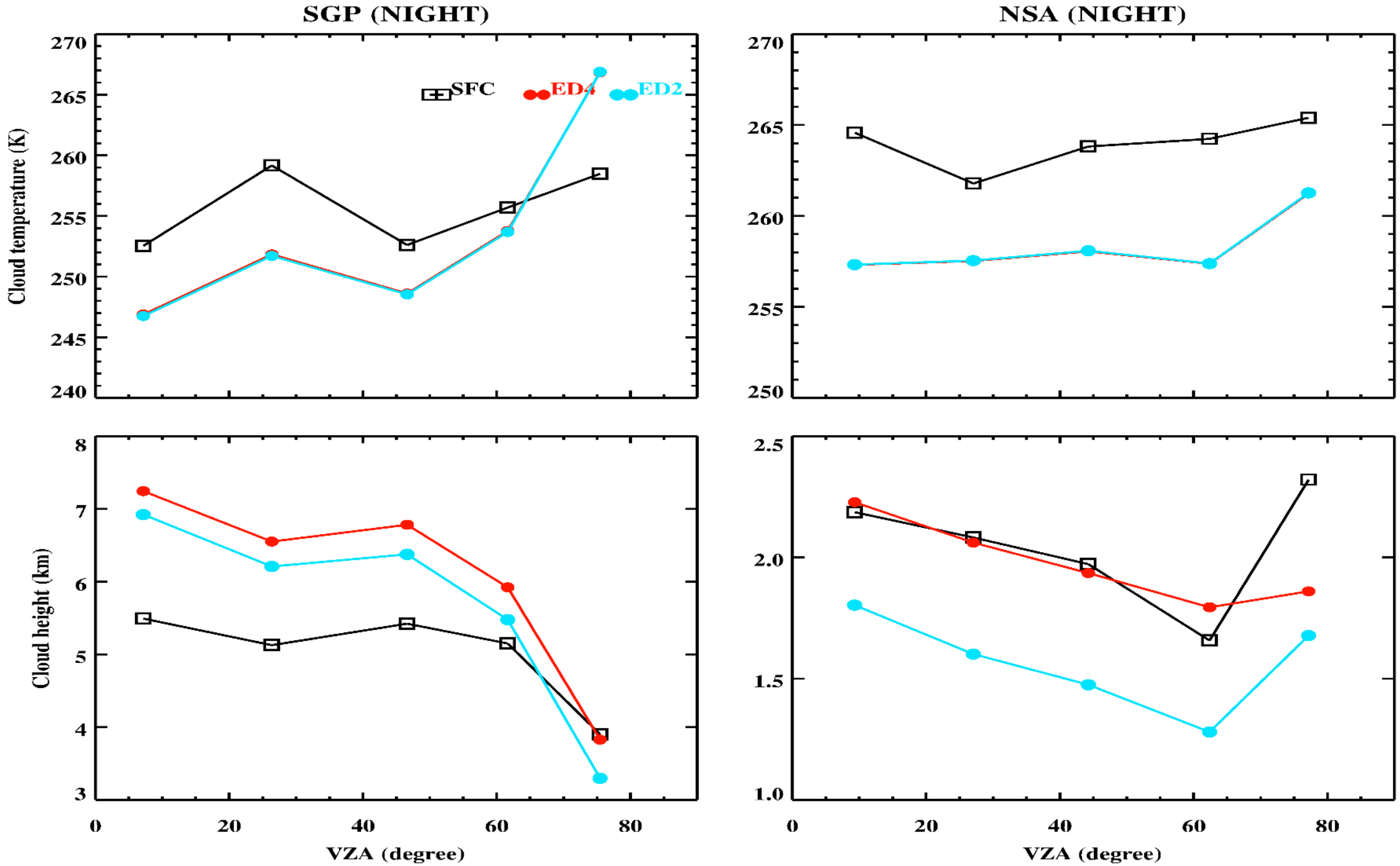
NSA (nighttime)



- For all types of clouds, T_{eff} of both CM Ed2 and Ed4 is close to T_b;
- Z_{eff} of CM Ed2 for all types of clouds are all lower than Z_t;
- Z_{eff} of CM Ed2 for all types of clouds are all lower than Z_t except single layer liquid clouds;
- For single layer liquid clouds, the Z_{eff} of Ed4 is ~ 200 meters higher than Z_t.



- Since we selected SSFs by using the difference less than 1 K between Ed2 and Ed4, no surprising the temperatures did not show any differences;
- Ed4 Cloud effective heights are higher than Ed2 at both sites with relatively larger change at SGP than NSA;
- Weak VZA dependence of T_{eff} and Z_{eff} at NSA, strong VZA dependence at SGP;
- If T_{eff} of CM is lower than T_{center} the Z_{eff} should be higher than Z_{center}, therefore, the relations hold over SGP site but not over NSA site.



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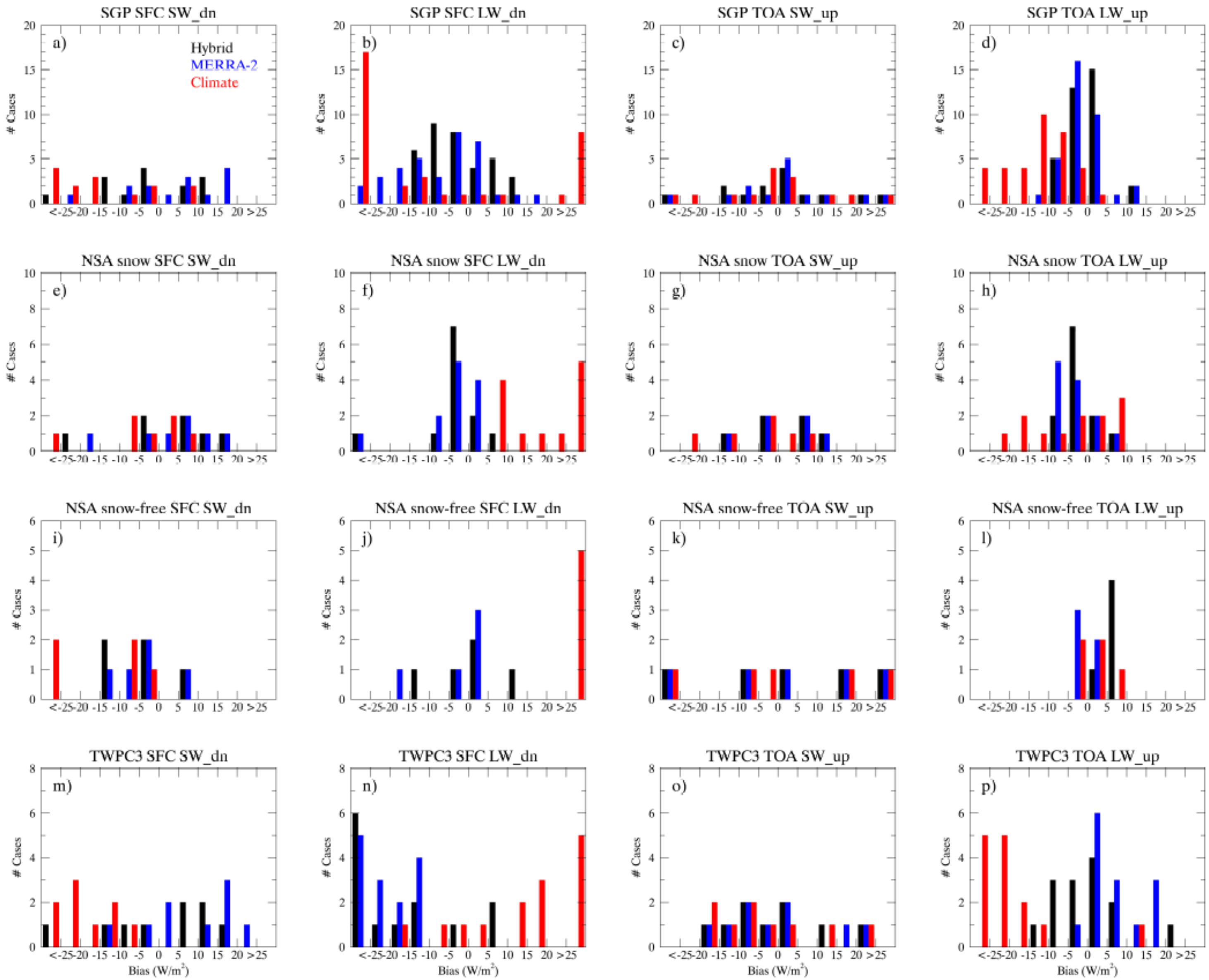
- Ed4 Cloud effective heights are higher than Ed2 at both sites with relatively larger change at SGP than NSA;
- Weak VZA dependence of T_{eff} and Z_{eff} at NSA, strong VZA dependence at SGP;
- If T_{eff} of CM is lower than T_{center} the Z_{eff} should be higher than Z_{center}, therefore, the relations hold over SGP site but not over NSA site.



SGP SFC SW_dn
SGP SFC LW_dn
SGP TOA SW_up
SGP TOA LW_up
NSA snow SFC SW_dn
NSA snow SFC LW_dn
NSA snow TOA SW_up
NSA snow TOA LW_up
NSA snow-free SFC SW_dn
NSA snow-free SFC LW_dn
NSA snow-free TOA SW_up
NSA snow-free TOA LW_up
TWPC3 SFC SW_dn
TWPC3 SFC LW_dn
TWPC3 TOA SW_up
TWPC3 TOA LW_up
a) b) c) d) e) f) g) h) i) j) k) l) m) n) o) p)
Hybrid
MERRA-2
Climate
Cases
<-25 -20 -15 -10 -5 0 5 10 15 20 >25
Bias (W/m^2)

Table 2: Averaged surface albedos (daytime only), scattering AODs, and skin temperatures from the selected cases at three ARM sites.

	SGP	NSA		TWPC3
		Snow ($\alpha \geq 0.3$)	Snow-free ($\alpha < 0.3$)	
Albedo	0.22	0.80	0.23	0.16
AOD_{scat}	0.13	0.08	0.07	0.14
Skin_T (K)	287	250	275	301

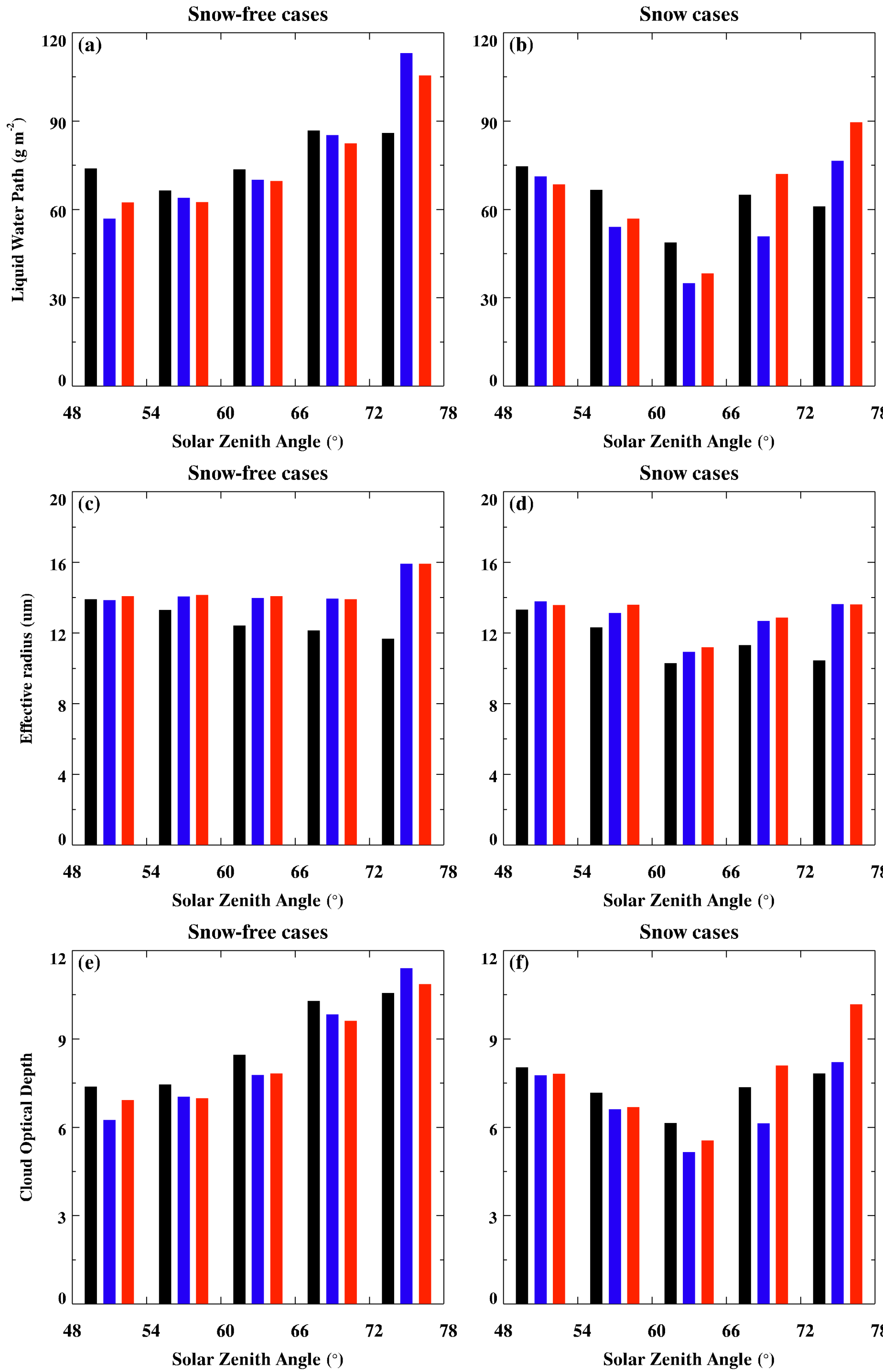
For cases without an AOD_{scat} observation, the AERONET 500 nm mean value was used (0.14, 0.08, and 0.14 for SGP, NSA, and TWP-C3, respectively).

The averaged surface and TOA radiative fluxes (W/m^2) from ARM/CERES observations and tuned RTM calculations with inputs from the three profiles.

	Surface		Top-of-Atmosphere	
SGP	SW_dn	LW_dn	SW_up	LW_up
Hybrid	662.74	290.75	166.80	270.41
MERRA-2	669.79	285.20	167.39	269.61
Climate	649.80	270.28	164.36	256.76
Observation	**665.20**	**292.58**	**165.66**	**270.47**
NSA *Snow ($\alpha \geq 0.3$)*				
Hybrid	162.95	155.95	147.67	194.30
MERRA-2	163.19	154.90	147.66	193.24
Climate	155.04	183.78	140.93	190.44
Observation	**160.48**	**159.58**	**145.67**	**195.61**
Snow-free ($\alpha < 0.3$)				
Hybrid	348.73	248.85	116.88	252.14
MERRA-2	349.65	245.74	117.09	246.88
Climate	335.13	299.55	113.00	248.01
Observation	**352.38**	**248.24**	**118.93**	**247.02**
TWPC3				
Hybrid	759.09	355.54	115.88	311.49
MERRA-2	767.56	353.95	116.89	319.55
Climate	736.03	398.24	113.89	286.70
Observation	**758.04**	**376.35**	**116.83**	**312.66**

The calculated flux 90% confidence intervals (W/m^2) $[\mu_{lower}^{*}, \mu_{upper}^{*}]$. Intervals of greater than 15% are omitted. The percent is determined as $[(\mu_{upper}^{*} - \mu_{lower}^{*})/X] \times 100\%$

	Surface		Top-of-Atmosphere	
SGP	SW_dn	LW_dn	SW_up	LW_up
Hybrid	[656.93,668.54]	[288.61,292.88]	[160.00,173.60]	[269.19,271.63]
MERRA-2	[664.17,675.41]	[282.04,288.37]	[160.68,174.10]	[268.11,271.11]
Climate	[640.57,659.13]	[257.21,283.36]	[156.33,172.38]	[254.25,259.27]
NSA *Snow ($\alpha \geq 0.3$)*				
Hybrid	[154.04,171.85]	[151.37,160.53]	[139.82,155.52]	[192.15,196.45]
MERRA-2	[154.73,171.64]	[149.66,160.14]	[139.93,155.39]	[190.87,195.60]
Climate	[145.03,165.05]	[174.85,192.71]	[132.23,149.63]	[185.32,195.56]
Snow-free ($\alpha < 0.3$)				
Hybrid	[340.73,356.73]	[240.31,257.40]	-----	[249.59,254.69]
MERRA-2	[342.35,356.95]	[236.64,254.85]	-----	[244.98,248.78]
Climate	[320.08,350.18]	[287.94,311.16]	-----	[243.27,252.75]
TWPC3				
Hybrid	[750.65,767.65]	[346.46,364.62]	[107.59,124.17]	[308.72,314.25]
MERRA-2	[760.10,775.02]	[349.96,357.93]	[108.92,124.87]	[316.84,322.26]
Climate	[729.74,742.33]	[387.38,409.09]	[106.22,121.56]	[282.35,291.05]



Snow-free cases
Snow cases
(a)
(b)
(c)
(d)
(e)
(f)
Liquid Water Path (g m^{-2})
Effective radius (um)
Cloud Optical Depth
Solar Zenith Angle (°)
0
30
60
90
120
4
8
12
16
20
3
6
9
48
54
60
66
72
78